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LETTER

CLASSICAL PSYCHOPHYSICS AND ELF MAGNETIC FIELD DETECTION

Each scientific discipline has a reference to the concept that the detection of a stimulus element within the entire set of observations is determined by the context or field within which the element occurs. Extremely low frequency (ELF) electromagnetic fields (EM) can be considered stimuli that are applied to a set (an organism, a cell or a chemical system). When they are applied, they are immersed in a matrix of other magnetic, electric and electromagnetic fields that compose the context. If the responses of living systems to ELF EM fields are related to the perceptual principles of other stimuli, then the ratio of the differences between ELF EM stimuli and their ambients cannot be ignored.

In classical psychophysics, the amount of change (increase or decrease) in a stimulus that is required to be detected as a difference from the background is systematically related to the absolute intensity of the background stimulus. That change in stimulus intensity (delta S) is called the j.n.d. or just noticeable difference; the intensity of the stimulus is usually designated as S. The ratio of delta S to S is often called the Weber fraction. It is a constant within the middle ranges of most sensory dimensions. This relationship has been called Weber's law and has been applied to all conventional sensory modalities.

To demonstrate the nature of the relationship, one convenient example might involve a constant of 0.01 or 1%. If this were assumed, then a change of 0.01 units of a stimulus would be required if the background stimulus measured 1 unit. A background of 10 units would require a change of 0.1 units

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while a reference of 100 units would require variations of a single unit. Each sensory system has more or less reliable Weber fractions. They are, for the various modalities: vision (brightness): 1/60; audition: 1/10; olfaction: 1/4; gustation: 1/3; proprioception: 1/50; and pain: 1/30 (1).

The sensory mechanisms by which magnetic fields are detected has been an area of much speculation. This is indeed an intriguing question since, unlike many other environmental stimuli whose impact upon the living system is restricted to specific boundary conditions, ELF magnetic fields can permeate the entire volume of the organism. However, we do not require the specification of a mechanism to treat the problem within the framework of classical perceptual principles.

Assuming that only some condition equivalent to a sensor or sensors exists, then a Weberian question arises: If an animal is exposed to a specific static field intensity (due to background fields, experimental fields or their combinations), how much change in field intensity is required to produce a detectable effect? References to awareness or consciousness are not required.

Close inspections of static magnetic fields (B; the equivalent of S), and time-varying fields (delta B; the equivalent of delta S) values within different laboratories suggest that different apparatus and locations would involve different values for delta B and B. Sometimes the time-varying component (delta B) may be approximately equal to or greater than the steady-field intensity (B), especially for larger values with essentially symmetrical polarities (10 mT S to 10 mT N). Other times, with some Helmholtz coil arrangements, there may be a constant DC component above or below the neutral condition (a + or - offset), upon which the time-varying field is superimposed. Some arrangements superimpose variable

The complexity of the fields are often enhanced by the idiosyncratic contributions of local man-made architectures, geological anomalies, or the interactions of the experimental fields with the background levels. These local field modifiers, for example, steel grids within concrete support pillars or near-surface mineral deposits, can either enhance local geomagnetic static field levels or reduce them to near-null levels.

When experimenters attempt to use very low intensity ELF fields, particularly those that approach steady-state geomagnetic values, the possibility of cancellation of the background field due to interaction between the experimentally generated flux lines and the geomagnetic sources becomes possible. Without specific measurement, the experimenters may not realize that the background steady state field condition of the animals may be a magnitude or more below geomagnetic values taken outside the range of the exposure area.

What would such variation mean? For discussion, we will assume that the "Weber fraction" is 1/100 or 0.01 or 1% for ELF magnetic field detection. In this instance, an intensity variation (peak to peak) of 0.5 μT (0.005 gauss) would be required in the presence of a static background of 50 μT (0.5 gauss) to evoke a discernable effect. If the ambient field was increased from 50 μT to 0.5 mT (5 gauss), then the delta B would be increased to 5 μT (.05 gauss) variation. If the ambient steady fields were elevated to 10 Kgauss (1 T), then the variation intensity would be 100 gauss.

More frequent conditions occur in the other direction. If the background intensity was lowered, by accident or design, towards null conditions, then a number of interesting possibilities arise. Reduction of the background steady field to less than 1 μT (0.01 gauss) could allow detection of changes within the microgauss range. This means that the organism could begin to detect

organism would be exposed to these stimuli in addition to the experimental fields.

In the rotating magnetic field configuration (for example), where two horseshoe magnets are rotated in opposite direction around the major axis, there is a slower period of a near-null ambient condition because of the slow drift of the cancellation points through the area of exposure (3). This is due to a fractional disparity between the rotation time of one magnet with respect to the other. The change is only detectable with constant monitoring and slowly drifts between a near zero to maximum value every 30 or so minutes. The effect is most pronounced for those sets of magnets whose intensity approaches the steady-state geomagnetic field.

Rats exposed to these fields have tended to show more variability in water consumption and ambulation compared to rats exposed to the more intense fields and to sham-field conditions. Recently we have noted that periods of perturbation in daily water consumption (more than 100% over baseline), accompany (within a day) very intense geomagnetic storms with Ap values that exceeded 100. These storms are relatively rare and it is only because of the continuous series of experiments with the same apparatus over many years that these observations have been made. Does this reduction in the ambient field intensity enhance the animal's capacity to detect (be effected by) still weaker fields from the environment?

The second aspect of near-null field reductions or enhancements is also related to the often ignored geomagnetic transient. The background field is not consistent in many places because of the existence of transient geomagnetic anomalies. These short-lived anomalies (4) are apparently generated by the interaction between geomagnetic perturbations and the local geology. The anomalies can increase the normal field by a factor of 3 and reduce the field by much more. The change can last for hours to days. Traditional methods of ELF research would not detect these changes since

background measures are usually made only once or twice, at the beginning and end of the study.

Implicitly this particular application of Weber's law to the detection of time-varying magnetic fields assumes that delta B is smaller than B. Using a perceptual metaphor, the figure (delta B) would become indistinguishable from the ground (B) as the Weber ratio approached 1.0. Thus if the Weber's constant was 1% and the background steady state field intensity was 0.1 gauss, the detection would begin to occur with time-varying fields whose amplitudes were around 0.001 gauss. As the amplitudes of these fields approached 0.1 gauss (and the background intensity remained the same), the discrimination between the figure and the ground would become more difficult. This failure is only a problem if the detection of the time-varying field presumes a comparator process whereby the figure and ground must remain discriminable.

If this relationship between the intensity of the time-varying magnetic field with respect to the intensity of the static background field occurred, then the detection of the former would be non-linear. Whereas no detection would occur if the amplitude of the time-varying field was too small (less than threshold), detection would be contaminated by problems of discrimination if the time-varying field approached background levels. The largest effect would occur within a narrow window of ELF amplitudes for each arrangement.

A very peculiar situation would arise if the delta B was larger than the background static component. With ratios of greater than 1, the time-varying fields would become the ground and the static field would be the figure (using the perceptual metaphor). This would change the detection system. Instead of a steady-state reference for a time-varying field, the reference now becomes time-varying. The operations of comparator mechanisms, by which differences between stimulus inputs over time are determined by comparing them to a common reference becomes more difficult. This situation might occur with even weak ELF fields (less than a μT) if the background field was inadvertently reduced to near-null levels.

A final application of classical perceptual concepts to the problem of ELF magnetic field detection addresses the other major parameter: the frequency of presentation, which is the number of times a particular signal, signature or stimulus element is presented. This concept has been sometimes expressed as pulse frequency. The actual element may have its own frequency or combination of them. The element may be a simple sinewave, a brief pulse, a combination of higher frequencies, or a polynomial wave form. Each element may or may not have a fixed duration. The physical parameters of the elements may be different from the actual presentation frequency to the organisms.

In a Weberian experiment, a person may hold a weight of 1 kg and be asked to determine when he can discern the j.n.d. as small increments of weight are added or removed. The duration of these increments are within the discrimination range of the temporal framework of the system, in this case, the human observer. The increments are not presented and removed in the order of milliseconds. These increments are too short. They are not added slowly in a ramp-like manner over several minutes. In this instance, the change is too small. The changes or the stimulus presentation must occur within the temporally discriminable limits of the system (on the order of 1 second).

Once this parameter is established, the total effect depends upon the frequency of the presentation of the stimulus. It too has optimal limits. If the optimal duration of increment is 0.5 seconds, then the frequency of the stimulus presentation cannot exceed 2 per second. If it does, then the stimulus is no longer a series of distinct stimuli. Instead they become a static and indistinguishable component of the background reference. In the case of a person holding a kg weight, the extra 20 gm (the j.n.d.) becomes a part of the continuous background field.

A more discrete demonstration that the detection of stimuli as a series of individual events is determined by their presentation frequency can be seen with critical fusion frequency or critical flicker fusion (CFF). It involves the numbers of presentations of a light flash required before the flashes

appear to become a continuous emission. If brief pulses of light are present at a rate of 8 pulses per second, the perceptual system (and the variety of systems associated with it, including awareness) can discriminate the elements. However there is some point where the number of elements fuse to become, perceptually at least, a continuous stimulus. At this point, the light flashes no longer exist as a phenomenon. No longer are they disrupting stimuli. Instead they become a type of continuous background. The same stimulus, presented at about 30 presentations per second appears as a continuous light beam.

The critical frequency for fusion is influenced by the field as well. The frequency of presentation can be considered the figure and the background static illumination can be considered the field. In a particular paradigm, a very bright background static illumination requires a higher frequency of stimulus presentations before they appear as a continuous light. A very dark background of illumination requires a much lower presentation frequency.

This well-known characteristic of the perception of light stimuli can be applied to ELF field research. Is there an analogous narrow window of frequencies that are effective stimuli before they become background constants? If detection of changing magnetic fields is analogous to changes in light fields, then there must be windows of frequency presentation. Presentation frequencies that are less than the optimal may not evoke a clear effect. Frequencies beyond the threshold would only blend into the background or become equivalent to a static field condition.

Windows of optimal presentation frequencies (the Adey effect) are of course well known in ELF research. This strongly suggests a non-linearity of some biological detection systems for electromagnetic fields whose presentation frequencies fall within the ELF range. The source of the actual stimulus may be sinusoidal ELF fields or higher frequency fields that are pulsed or presented within the ELF range. The critical feature appears to be the frequency of presentation of the stimulus elements.

This comparison between classical psychophysics and electromagnetic fields has ignored the distinction between effect and detection. I have assumed that for the most part detection and effect are highly correlated. Detection, however, does not necessarily include "awareness" in a human sense. It is also realized that there may be fundamental differences between detection and effect mechanisms. They would be similar to the difference between detection of cells (by receptors) and the effects of this detection through coupling between receptors and the mechanisms that elicit changes in the cytoplasm.

There are may similarities between the kinds of detection problems found in contemporary ELF EM research and the early days of classical psychophysics. The optimal ratios between the changing stimulus and the background stimulus and the non-linear relationships between the frequency of stimulus presentation and the detection of either discontinuous or continuous phenomena are two examples. Indeed the similarities may be superficial. But if they are not, then the optimal parameters may be more situation-specific than previously presumed.

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